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Original Article

HYPO SLUDGE – AN INNOVATIVE AND SUSTAINABLE APPROACH

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ABSTRACT

The increasing amount of wastes is a concerning reality that has arose the sustainability issues for the environment. Large amount of wastes such as fly ash (from thermal plant), hypo sludge (from paper mill industry) etc. are generated annually. Their disposal generally by landfills leads to environmental pollution. Also, the production of cement accounts the global warming by releasing carbon dioxide. Therefore an innovative use of the industrial wastes in concrete formulation as the supplementary cemetatious material can help in minimizing the environmental problem. This research work is concerned with the experimental investigation of the strength of concrete blended with hypo sludge. The cement has been replaced by hypo sludge in the range of 0%, 5%, 10%, 15% and 20% for M-20 mix. Concrete mixtures were produced, tested and compared with the conventional concrete mix in the terms of workability, compressive strength and splitting tensile strength. The tests were carried out after 7, 14 and 28 days. The workability of concrete decreases with the increase in content of hypo sludge The gradual increase was seen in compressive strength and splitting tensile strength of concrete blended with 0% to 10% of hypo sludge content for all curing ages. Beyond that there is a significant reduction in strength. The maximum compressive strength and splitting tensile strength were 27.62 N/mm^2 and 3.79 N/mm^2. Also the cost analysis indicates that with incorporation of hypo sludge decreases the cost of concrete, but at the same time strength also decreases. 20% replacement of cement with hypo sludge leads to 18.35% reduction in cost.

KEYWORDS: Hypo Sludge, Workability, Compressive Strength, Splitting Tensile Strength, Cost

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INTRODUCTION

The concept of recycling and sustainability has been introduced to maintain the level natural resources. Industrial wastes are being produced per annum by chemical and agricultural process in India. By the inclusion of industrial waste in concrete, the energy and the environment can be saved. The use of these by-products offers environmental advantages like divert the material from the waste stream, reduce the energy used in processing virgin materials, use of virgin materials, and decreases pollution. To produce ordinary portland cement we use earth resources like limestone. During manufacturing of one tonne of ordinary portland cement an equal amount of carbon-dioxide is released into the atmosphere which is harmful to the environment. So there is a need to choose an alternative [7]. In urban cities, solid waste management is one of the most challenging issues, which is a serious pollution problem due to the generation of huge quantities of solid waste [8]. Also, the cost of cement is also steadily increasing day by day. So, there is a great need to use industrial waste products in an appropriate manner to reduce cost and environmental problems [10].

Paper mill sludge is a major economic and environmental problem for the paper and board industry.

The material is a by-product of the de-inking and re-pulping of paper [11].The pulp and paper industry generates large volume of waste called Hypo sludge; which is technology-dependent but the estimate is around 100 tons of waste for 550 tons of pulp production which causes the problem to the environment [9]. The amount of sludge generated by the recycled paper mill depends on the furnish being used and end product being manufactured. Paper fibre can be recycled only a limited number of times before they become too short or weak to make high quality of paper.

Hypo sludge contains, low calcium and maximum calcium chloride and minimum amount of silica. Hypo sludge behaves like cement because of silica and magnesium properties. This silica and magnesium improve the setting of the concrete. Paper sludge consists of cellulose fibers, calcium carbonate and china clay and residual chemicals bound up with water. Hypo sludge contributes beneficial properties to the concrete while helping to maintain economy. Therefore, numerous contemporary researches have focused on the application of hypo sludge in cement and concrete production to attain sustainable development. Many researchers have investigated the feasibility of using the paper industry waste in concrete production as partial replacement of cement. The use of hypo sludge in concrete can save the paper industry disposal costs and produces a green concrete for construction [12]. Moreover, all the generated residues from cellulose and paper manufacturing are classified as not dangerous in the Catalogue of European Residues (CER). The current residues produced in the manufacture of paper, which are used in the ceramics industry and in agricultural compost, are catalogued as clean [6].

This research work describes the feasibility of using hypo sludge in concrete production as partial replacement of cement. The mix were blended with various proportion of hypo sludge in concrete, tested and compared with the conventional concrete.

MATERIALS USED

Cement

Ordinary Portland cement (OPC) of grade 43 from a single lot was used in this study. Cement conforming to specifications given in BIS: 8112-1989 was used. Cement was carefully stored to prevent the deterioration in its properties due to contact with the moisture. It was free and free from lumps. Table 1 shows the properties of OPC 43 grade.

Table 1: Properties of OPC 43 Grade Cement

Sr. No.	Characteristics	Value Obtained Experimentally	Values Specified By IS: 8112-1989
1.	Specific Gravity	3.15	-
2.	Standard consistency	31.5%	-
3.	Initial Setting time	140 minutes	30 minutes (minimum)
4.	Final Setting time	270 minutes	600 minutes (maximum)
5.	Compressive Strength 3 days 7 days 28 days	 24.60 N/mm^2 35.87 N/mm^2 48.45 N/mm^2	 23 N/mm^2 33 N/mm^2 43 N/mm^2

Fine Aggregates

Fine aggregates were collected from Chakki River (Pathankot). It was coarse sand, brown in colour. Specific gravity of fine aggregates was experimentally determined as 2.72. Fine aggregates are confirming to grading zone II as per BIS-383:1970 are shown in Table 2.

Table 2: Sieve Analysis of Fine Aggregates Total Weight of Sample = 500 G

Is- Sieve Designation	Weight Retained on Sieve (G)	%age Weight Retained on Sieve	Cumulative %Age Weight Retained on Sieve	%Age Passing	%Age Passing For Grading Zone-Ii as per Is: 383-1970
10 mm	Nil	Nil	Nil	100	100
4.75 mm	40	8.00	8.00	92.00	90-100
2.36 mm	23	4.60	12.60	87.40	75-100
1.18 mm	73	14.60	27.20	72.80	55-90
600 micron	111	22.20	49.40	50.60	35-55
300 micron	123	24.60	74.00	26.00	8-30
150 micron	120	24.00	98.00	2.00	0-10

Coarse Aggregates

The coarse aggregates used were a mixture of two locally available crushed stone of 10 mm and 20 mm size in 50:50 proportions. The aggregates were washed to remove dirt, dust and then dried to surface dry condition. Specific gravity was found to be 2.65. Coarse aggregates are confirming to grading zone II as per BIS-383:1970 are shown in Table 3.

Table 3: Sieve Analysis of Proportioned of Coarse Aggregates

Is- Sieve Designation	Weight Retained on Sieve (10 Mm Agg. (G)	Weight Retained on Sieve (20mm Agg. G)	50:50 Proportion (10 Mm: 20mm) Weight Retained	Cumulative Weight Retained (G)	Cumulative %Age Weight Retained	% Age Passing	Is: 383-1970 Requirements
80 mm	Nil	Nil	Nil	Nil	Nil	100	100
40 mm	Nil	Nil	Nil	Nil	Nil	100	100
20 mm	8	5	5.60	5.60	0.28	99.72	95-100
10 mm	587	1973	1278	1283.6	64.18	35.82	26-55
4.75 mm	1265	22	646.5	1930.1	96.50	3.50	0-10

Hypo Sludge

Hypo sludge obtained from Shreyans Paper Mill Ltd (Ahmedgarh) was used in this study. Hypo sludge was sun dried till the moisture exhaust and after that it was grinded. The properties of hypo sludge and its comparison with cement are given in Table 4.

Table 4: Comparison of the Properties of Hypo Sludge with Cement

Serial No.	Constituents	Cement (%)	Hypo Sludge (%)
1	Lime (CaO)	62	46.2
2	Silica (SiO_2)	22	9
3	Magnesium oxide (MgO)	5	3.33
4	Aluminum (Al2O3)	1	3.6
5	Calcium sulphate (Ca_2SO_4)	4	4.05

Water

Fresh and clean tap water was used for casting the specimens in the present study. The water was relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per BIS: 456-2000.

LABORATORY TESTING PROGRAM

Mix Design and Sample Preparation

Theoretical proportion of different ingredient of plain cement concrete of grade M-20 is determined following the guidelines of IS 10262- 2009. Then 4 mixes were prepared other than control mix at different replacement levels of cement with hypo sludge (0%, 5%, 10%, 15% & 20%). The water/cement (w/c) ratio in all the mixes was kept 0.50 and water content in each mix was 186 L/m^3. The ratio of different materials used in each mix and mix designation are given below in Table 5. The degree of workability was found using slump test. To determine the compressive strength (as per BIS: 516 - 1959) and splitting tensile strength (as per IS: 5816: 1999) the cubes of size 150mm were casted and tested after 7, 14 and 28 days of curing under Universal Testing Machine (UTM).

Table 5: Mix Proportions of Different Concrete Mixes

Mix	W/C Ratio	Hypo Sludge %	Hypo Sludge (Kg/M^3)	Cement (Kg/M^3)	Fine Aggregates (Kg/M^3)	Coarse Aggregates (Kg/M^3)	Water (L/M^3)
M1	0.55	0	0	338	749.7	1142.4	186
M2	0.55	5	16.9	321.1	749.7	1142.4	186
M3	0.55	10	33.8	304.2	749.7	1142.4	186
M4	0.55	15	50.7	287.3	749.7	1142.4	186
M5	0.55	20	67.6	270.4	749.7	1142.4	186

RESULTS AND DISCUSSIONS

Workability

Workability of concrete was tested using slump test apparatus immediately after preparing fresh concrete. The slump value for each mix with and without hypo sludge is given in Table 6.

Table 6: Test Results for Workability of Concrete

Mix	Hypo Sludge (%)	Slump(Mm)	Degree of Workability
M1	0	100	Medium
M2	5	95	Medium
M3	10	90	Medium
M4	15	80	Medium
M5	20	70	Medium

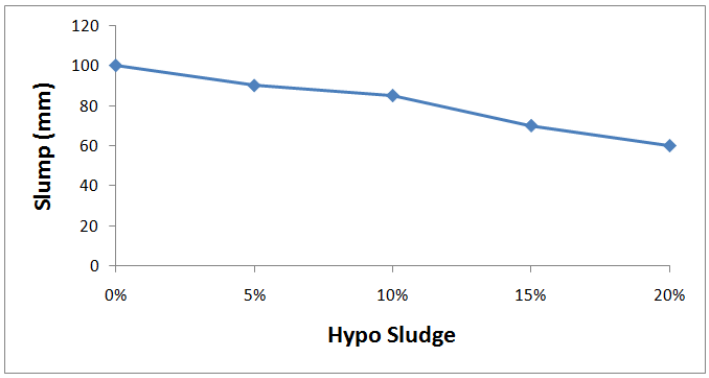

Figure 1: Slump Value of Concrete with Different Replacement Levels of Cement with Hypo Sludge

From Figure 1, it was observed that the workability of concrete decreases as the content of hypo sludge increases. The slump for 0% hypo sludge was 100mm, while slump for 20% hypo sludge was 70mm. This is due to the fact that hypo sludge exhibits high water absorption capability. When higher amount of hypo sludge was added in the mixture, the water demand of the mix rises which leads to the reduction in workability of concrete

Compressive Strength of Concrete

The compressive strength of all the mixes was determined at the ages of 7, 14 and 28 days for the various replacement levels of hypo sludge (0%, 5%, 10%, 15% and 20%) with cement. The average mean values of strength are given in Table 7.

Table 7: Test Results for Compressive Strength of Concrete

Mix	Hypo Sludge (%)	7 Days (N/Mm^2)	14 Days (N/Mm^2)	28Days (N/Mm^2)
M1	0	15.86	22.21	26.9
M2	5	16.01	23.75	27.11
M3	10	18.13	24.05	27.62
M4	15	15.48	20.96	23.4
M5	20	12.16	16.22	20.25

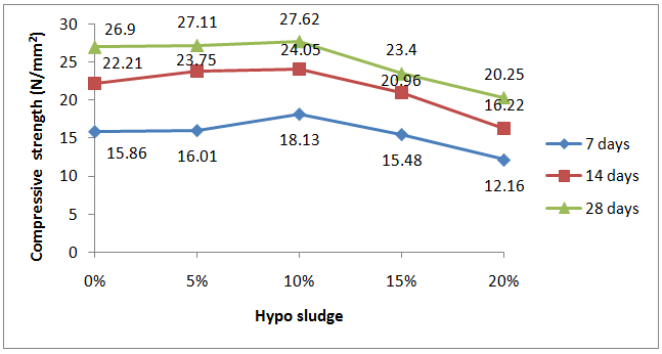

Figure 2: Compressive Strength of Concrete with Different Replacement Levels of Cement with Hypo Sludge

Figure 2 shows the variation of compressive strength of concrete with different replacement levels of hypo sludge with cement. It can be observed that the compressive strength of concrete increase up to 10% of hypo sludge. Then after, the compressive strength decreases. The percentage change in compressive strength for 5%, 10%, 15% and 20% of hypo sludge was 0.78, 2.68, -13.01 and -24.72 respectively after 28 days of curing. There was significant reduction in compressive strength due to water absorbing capability of hypo sludge which disturbed the water cement ratio. At higher dosage of sludge, cement content decreases which leads to the weak bonds especially around sludge particles. This eventually caused early crack development during compressive test.

Splitting Tensile Strength of Concrete

The splitting tensile strength of all the mixes was determined at the ages of 7, 14 and 28 days for the various replacement levels of hypo sludge (0%, 5%, 10%, 15% and 20%) with cement. The average mean values of strength are given in Table 8.

Table 8: Test Results for Split Tensile Strength of Concrete

Mix	Hypo Sludge (%)	7 Days (N/Mm^2)	14 Days (N/Mm^2)	28days (N/Mm^2)
M1	0	1.75	2.99	3.22
M2	5	1.81	3.16	3.6
M3	10	2.00	3.54	3.79
M4	15	1.40	2.39	2.98
M5	20	1.28	2.20	2.42

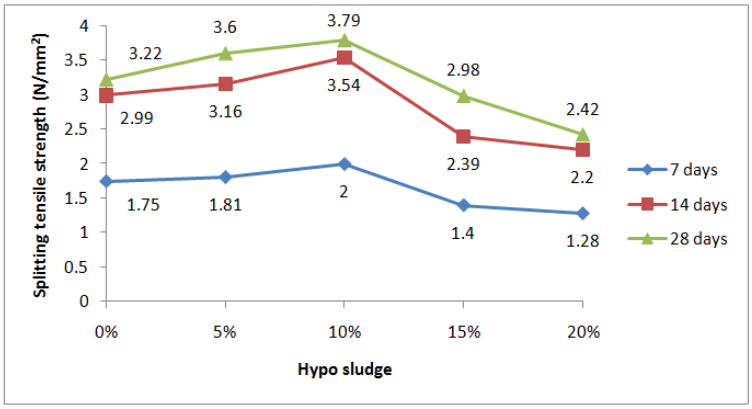

Figure 3: Splitting Tensile Strength of Concrete with Different Levels of Hypo Sludge at Different

Curing Ages

Figure 3 shows the variation of splitting tensile strength of concrete with different replacement levels of hypo sludge with cement. It can be observed that the splitting tensile strength of concrete increase up to 10% of hypo sludge. Then after, the spitting tensile strength decreases. The percentage change in splitting tensile strength for 5%, 10%, 15% and 20% of hypo sludge was 11.80, 17.70, -7.45 and -24.84 respectively after 28 days of curing. It is seen that the results coincide with the results of compressive strength due to the same reasons as stated earlier.

Cost Feasibility of Concrete When Blended with Hypo Sludge (Waste Material)

Table 9 and Table 10 shows the rate (Rs./Kg) for cement and hypo sludge and cost analysis of different mix blended with hypo sludge respectively.

Table 9: Rate (Rs. /Kg) For Cement and Hypo Sludge (* Only Grinding Charges)

Sr. No	Material	Rate (Rs./Kg)
1	Cement	6.5
2	Hypo sludge	0.50*

Table 10: Cost Analysis for Mix Blended with Hypo Sludge (Waste Material)

Mix	Cement (Kg/M^3)	Rate (Rupees/Kg)	Hypo Sludge %	Hypo Sludge (Kg/M^3)	Rate (Rupees/Kg)	Total Cost (Rupees/Kg)	% Change in Cost
M1	338	2194	0	0	0	2194	0
M2	321.1	2087.15	5	16.9	8.45	2095.6	-4.48
M3	304.2	1977.3	10	33.8	16.9	1994.2	-9.11
M4	287.3	1867.45	15	50.7	25.35	1892.8	-13.73
M5	270.4	1757.6	20	67.6	33.8	1791.4	-18.35

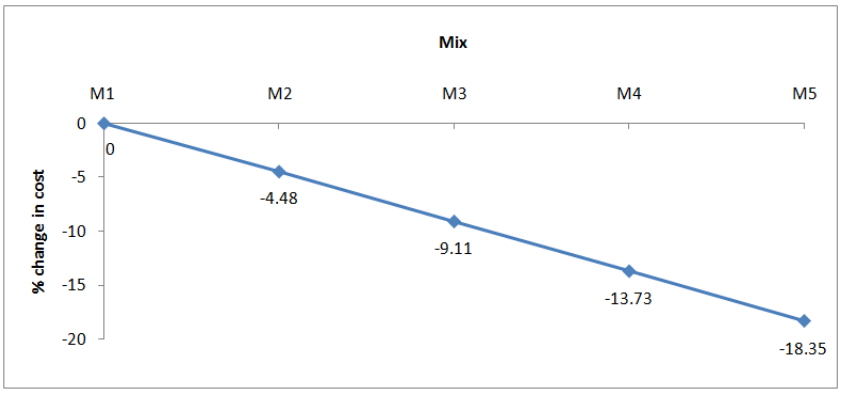

Figure 4: Percentage Change in Cost for Mix Blended with Hypo Sludge Only

Since the cost of hypo-sludge is negligible, so it can widely be used in areas near by paper mill. The cost analysis indicates that with incorporation of hypo sludge decreases the cost of concrete, but at the same time strength also decreases. Thus it has been established that to some extent, the use of hypo sludge (paper industry waste) in concrete can save the disposal costs and can produce a greener concrete for construction.

CONCLUSIONS

A better measure towards the sustainable environment can be undertaken by effective utilization of hypo sludge in concrete. The environmental effects due to disposal of waste from the paper mill industry and residual amounts of cement manufacturing industry can be minimized through this research. Up to 10% of hypo sludge concrete attains the maximum compressive strength and splitting tensile strength. The cost analysis indicates that with incorporation of hypo sludge decreases the cost of concrete, but at the same time strength also decreases. The material is economically feasible for the temporary shelters during natural disasters where strength is not considerable factor.

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